Regional Operational Plan SF.4A.2013.08

Effectiveness Monitoring of a Fish Passage Replacement Project in Buddy Creek, Mat Su Borough

by

Gillian O'Doherty

November 2013

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$log_{2,}$ etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

REGIONAL OPERATIONAL PLAN SF.4A.2013.08

EFFECTIVENESS MONITORING OF A FISH PASSAGE REPLACEMENT PROJECT IN BUDDY CREEK, MAT SU BOROUGH

by

Gillian O’Doherty

Alaska Department of Fish and Game, Division of Sport Fish, Anchorage

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November 2013

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SIGNATURE PAGE

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Project leader(s):	Gillian O'Doherty
Division, Region, and Area	Division of Sport Fish, Region IV, Anchorage
Project Nomenclature:	
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Field Dates:	June 2013 to October 2014
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Approval

Title	Name	Signature	Date
Project leader	Gillian O'Doherty	Gillian O'Doherty	7/1/13
Biometrician	Pat Hansen	Pat Hansen	6/13/13
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ABSTRACT

The primary goal of this study is to test the hypothesis that successful upstream passage of juvenile coho salmon will be observed over a wider range of stream discharges after the existing crossing is replaced with a stream simulation culvert. For both the before and after studies, fish will be marked with unique passive integrated transponder (PIT) tags and monitored with tracking devices (a Streamwidth PIT tag Interrogation system or SPI). There will be two SPIs installed at the site, one above and one below the culvert in order to track fish movement through the site. We will measure passage through the culvert when the same fish is detected first below and then above the crossing. A stream gage will be installed adjacent to the project site and will allow us to relate fish movements through the crossing to stream discharges. This data will be used to improve our understanding of the effects of multiple culvert batteries and undersized culverts on the passage of juvenile salmonids.

Key words: fish passage, coho salmon, Chinook salmon, PIT tag, juvenile salmonid fish passage, culvert, Sawyer Creek, Buddy Creek, Matanuska Susitna Borough

PURPOSE

The purpose of this project is to observe the effectiveness of a fish passage improvement project on actual measured fish passage. The project will take place at the crossing of Sawyer's Shady St and Buddy Creek in the Matanuska Susitna Borough (MSB). The existing crossing is comprised of three undersized culverts and is believed to be impassable to young of the year salmonids at many flows. The culvert will be replaced midway through the monitoring project with a stream simulation type culvert which is designed to not impeded fish passage at any flows. The Alaska Department of Fish and Game (ADF&G), the MSB and the United States Fish and Wildlife Service (USFWS) are partnering on the replacement of 10 such crossings in the MSB between 2013-2015 and this project will provide direct feedback on the effectiveness of the technique.

BACKGROUND

Historically culverts were placed in streams with little or no consideration for effects on the stream channel or for aquatic organisms. Perched culvert outlets, excessive water velocities, constricted stream channels, debris plugged culverts or culverts with inadequate water depth often impact fish passage by delaying or impeding fish movements. One study estimated the loss in habitat from culverts on forest roads as 13% of the total decrease in coho salmon summer rearing habitat in the Skagit river basin in Washington State (Beechie et al., 1994).

Fish passage barriers are particularly damaging to anadromous fish, such as coho salmon Oncorhyncus kisutch, Chinook salmon O. tshawytscha, steelhead O. mykiss, and sea-run cutthroat trout O. clarkii clarkia which must migrate from saltwater to freshwater to complete their life cycles. Unrestricted access via stream corridors to spawning, rearing and overwintering habitats is essential to maintaining salmonid production as well as healthy populations of resident trout and other fish (Jackson 2003). Movement of juvenile salmon and resident trout has been observed in response to a variety of environmental factors, including high and low flow events, changes in stream temperature, predation pressure, population densities and the availability of food or shelter (Gowan et al. 1994; Robison et al. 1999; Kahler and Quinn 1998). Studies in coastal Washington streams documented the movement of juvenile coho salmon, steelhead trout and coastal cutthroat trout and determined that movers grew faster than non-movers (Taylor and Love 2003). One study estimated the loss in habitat from culverts on forest roads as 13% of the total decrease in coho salmon summer rearing habitat in the Skagit river basin in Washington State (Beechie et al., 1994).

The MSB is one the most populous and rapidly growing areas of Alaska. One consequence is the rapid development of local road networks. The salmon and trout produced in MSB streams support commercial, sport, and recreational fishing industries and contribute in excess of several hundred million dollars to the Southcentral Alaska economy. In recent years Chinook salmon returns to the MSB have been low, resulting in a significant drop in sport fishing related services across MSB. While there are many potential reasons for this collapse, ensuring that juvenile fish have the best chance of accessing preferred habitats is an important step to protect fisheries populations.

Over the past 10 years approximately 70 fish passage projects have been carried out in the Mat Su Borough in an effort to protect fish populations; however project monitoring has been limited to construction inspections and as built surveys (O'Doherty and Eisenman, *In prep*). ADF&G has successfully carried out a similar project, funded by AKSSF, in 2007-2009 on Slikok Creek near Sterling, AK and much of the same equipment and methods would be used to carry out this project. This project will directly examine fish passage rates through an existing culvert and a newly constructed stream simulation type culvert in order to compare the ability of fish to pass upstream through the culvert over the annual range of flows. The study will focus on juvenile salmonids, as the majority of ADF&G assessment work does, and will directly observe fish movement through the project area. The results of this project will be used to improve our understanding of existing fish passage barriers and improve efforts to prioritize replacement.

OBJECTIVES

1. Test the hypothesis that successful upstream passage of juvenile coho salmon will be observed over a wider range of stream discharges after the existing crossing is replaced with a stream simulation culvert. Specifically, we will test the null hypothesis that the variance of stream discharge with successful upstream passage is the same before and after the crossing is replaced against the alternative hypothesis that that the variance is greater after the replacement with the probability of type I and type II error being 0.05 and 0.10 respectively.

2. Test the hypothesis that average velocities inside the culverts will increase at a greater rate than in the adjacent stream channel as discharges increase. We will look at velocities up to the bankfull discharge, estimated to be approximately 100 cubic feet per second (cfs).

SECONDARY OBJECTIVES:

1. Identify up and downstream migration windows for juvenile salmonids and resident trout in Buddy Creek.

2. Collect data on the movement of fish from Montana Creek into Buddy Creek.

3. Compare length frequency distributions of captured juvenile Chinook and coho salmon.

For Objective 1, the range of discharges over which successful passage occurs may be further compared by species and direction of travel (upstream or downstream) if the data can provide estimates with adequate precision and confidence.

METHODS

The intent of this project is to compare the ability of juvenile fish to pass through an existing crossing structure with the ability to pass through a replacement structure over a range of discharges in order to better understand the impact of an undersized crossing on fish movement. We are primarily interested in the upstream movement of juvenile coho salmon.

The selected crossing is in Buddy Creek (Figure 1) and has been determined by ADF&G's fish passage program to be "Red" or likely to impede passage using the ADF&G standard Level 1 fish passage assessment (O'Doherty and Eisenman *In review*). The structure consists of three culverts, one of which is slightly perched and all of which are undersized relative to the stream (Figure 2). The existing structure is predicted to have increased water velocities inside the culverts compared to the adjacent stream channel due to constriction and the increased water velocities are believed to impact the passage of juvenile fish. Objective 1 of this study is to examine the impacts on juvenile fish.

The crossing is scheduled to be replaced with a single stream simulation type culvert in the summer of 2014. Stream simulation culverts are culverts that, to the extent practical, conform to the following guidelines:

- Size: The diameter of the culvert will be greater than the stream's natural ordinary high water (OHW) width. For narrow channels with wide floodplains, additional overflow culverts will be considered.
- Gradient: The culvert gradient will be within 1% of the natural stream gradient.
- Embeddedness: Culverts will be embedded no less than 20% below the naturally projected bed scour depth and no more than 40%.
- Substrate: Culverts will be back-filled with the same size and size fraction of sediment as the naturally occurring stream sediment in order to create a channel through the culvert that is largely indistinguishable from the natural channel in adjacent stream reaches.
- Banks: Care will be given to mimic stream conditions during low flow conditions such that the low flow channel within the culvert has similar depth and velocity to the natural stream. Often this requires utilizing substrate to mimic the stream bank lines within the culverts.
- Capacity: The culverts will pass a 100-year storm flow at less than 100% of the culvert's height. This allows for passage of other watershed products (large wood, debris, and substrate) during extremely high flows.
- Channel: Stable stream banks upstream and downstream of the crossing will be maintained or constructed to prevent scour and sedimentation.

The planned time-line will allow us to do a "Before" replacement assessment of fish passage and velocities in 2013/2014 and an "After" culvert assessment 2014/2015. The entire assessment will be completed in October of 2015.

For both the before and after studies, fish will be marked with unique passive integrated transponder (PIT) tags and monitored with tracking devices (a Streamwidth PIT tag Interrogation system or SPI). There will be two SPIs installed at the site, one above and one below the culvert in order to track fish movement through the site. We will measure passage through the culvert when the same fish is detected first below and then above the crossing.

A stream gage will be installed adjacent to the project site and will allow us to relate fish movements through the crossing to stream discharges.

STUDY AREA

The main stem of Buddy Creek is about 12.1 kilometers in length, with one tributary of approximately 4km. It originates in wetlands located at approximately 1,100 feet elevation in the foothills of the Talkeetna Mountains near the headwaters of Goose Creek (Figure 1). Buddy Creek is an anadromous stream providing rearing habitat for coho salmon and rainbow trout and is a tributary to Montana Creek which provides spawning habitat for Chinook, chum, pink and coho salmon as well as rearing habitat for Chinook salmon (ADF&G, *In prep*). Chinook salmon juveniles typically have freshwater residence for 1 year whereas coho salmon may reside between 1 and 3 years in freshwater years. Coho salmon are known to be present at the study site. Chinook salmon are known to occur downstream in Montana Creek but have not been recorded in Buddy Creek to date.

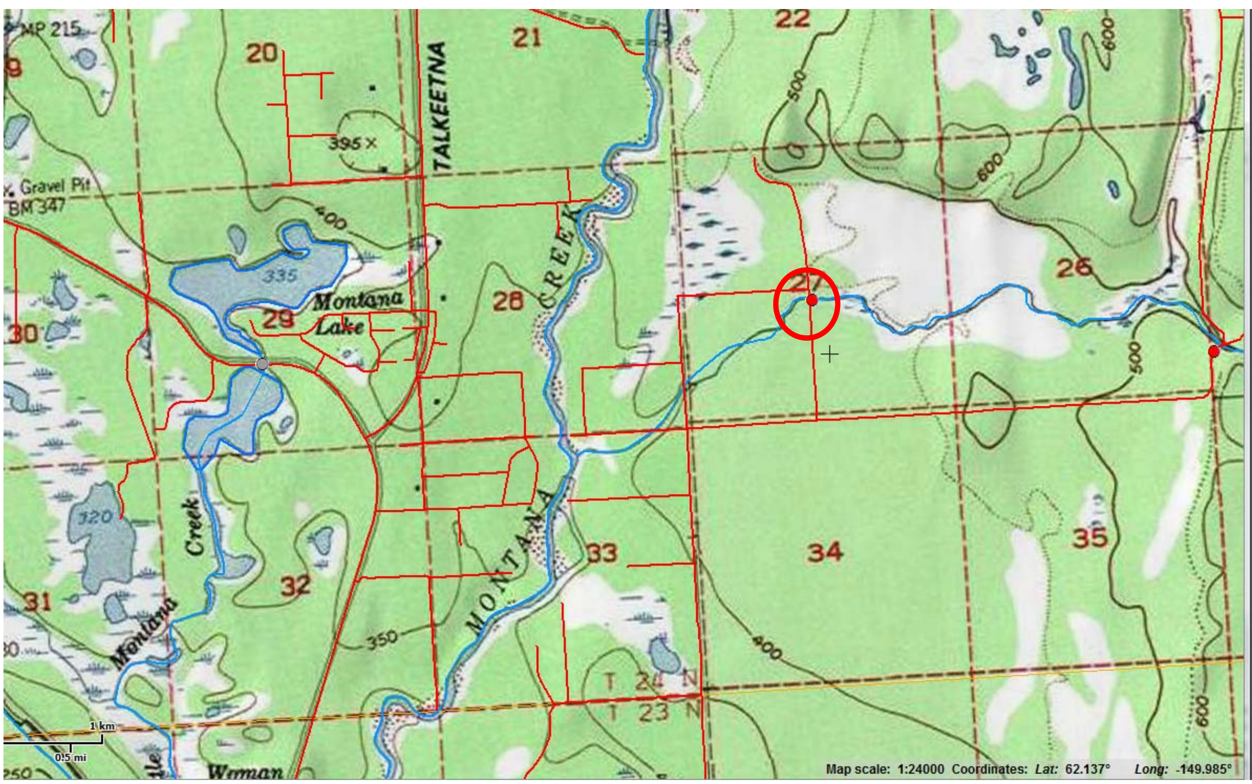

Figure 1. Location of Buddy Creek, showing both crossings and confluence with Montana Creek. The upstream crossing will be replaced in June of 2013 and the study crossing (circled in red) will be replaced in 2014.

Figure 2.–The existing crossing at Buddy Creek and Sawyer's Shady St. This figure shows the outlet at summer flows.

Figure 3. Example of stream simulation culvert showing stream channel through culvert and banks.

The study crossing is located on a dirt road called Sawyer's Shady Street, a Matanuska Susitna Borough right of way, and is approximately 1 mile upstream of the confluence with Montana Creek. There are no known barriers downstream. There is another culvert upstream which is scheduled to be replaced in June of 2013 at the start of this study and is not expected to impact fish movement thereafter. The crossing on Sawyer's Shady St. is scheduled to be replaced in 2014 by the Matanuska Susitna Borough. Both replacement crossings will consist of a single stream simulation type culvert.

Two SPIs will be installed in the channel one upstream and one downstream of the culverts. They will be installed approximately 50' from the crossing. Gaging equipment will be located upstream in a suitable location no more than 400' from the culvert.

Figure 4. Example of an SPI in Slikok Creek near Soldotna, AK.

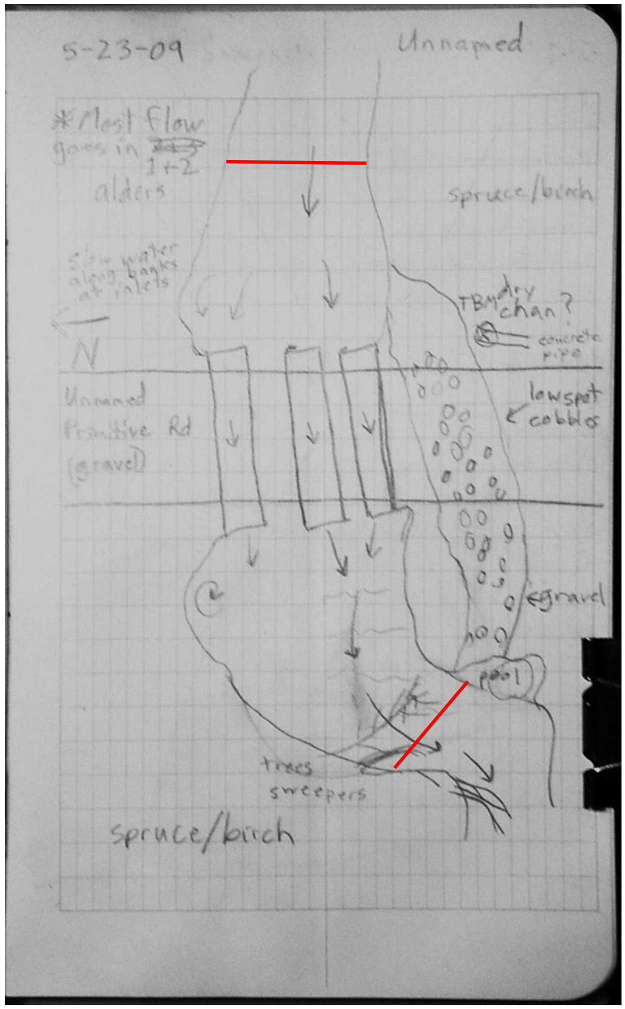

Figure 5. Map of the site. Locations of SPIs shown in red.

Figure 6. View downstream from the road towards the site of the downstream SPI.

Figure 7.–View looking upstream from the road (at high water) showing the location of the upstream SPI .

Research has shown juvenile salmonids migrate varying distances from a tagging release location. An ongoing study in nearby Meadow Creek has shown juvenile fish moving extensively throughout the system with one juvenile coho observed to travel 14km upstream in one season (Jon Gerken, USFWS personal communication). Other studies have shown that juvenile salmonids move shorter distances including: less than 100m but up to 500m (Bryant and Lukey 2004), ~5m to 23m (Roussel et al. 2004). Our goal is to observe as many tagged fish as possible moving upstream through the study area and therefore we will concentrate our tagging efforts downstream of the crossing, in Buddy Creek and in Montana Creek near the confluence. Tagging some fish in Montana Creek will allow us to observe those fish if they move into Buddy Creek to rear or to overwinter.

CULVERT DESCRIPTION

The existing culvert (Figure 1) was previously assessed using established criteria for measurements for fish passage (O'Doherty & Eisenman*, In review*) and classified as "Red" or likely to impeded juvenile fish passage. Collected data included physical characteristics of the culvert (length, diameter, corrugation size, embeddedness) and surveyed elevations of the pipe (inverts) and stream characteristics (a longitudinal profile through the project area). To document physical changes in the culvert and stream we will collect these data again at the beginning of the study and each year in May throughout the project duration.

A temporary benchmark (TBM) will be set up adjacent to the site and maintained throughout the project period in order to allow us to relate all survey and stage data collected at the site.

HYDROLOGY AND STREAM CHARACTERISTICS

Objective 1 of this study is to relate juvenile salmonid movement through the crossing to stream discharge and the following hydrology data will be collected to calculate an hourly average discharge (Q):

1. stream stage (0.01ft), daily at 15 minute intervals at the gaging station,
2. discharge (Q) measurements over low, medium and high water levels, in order to create a stage/ discharge relationship,

Objective 2 of this study will relate the average velocity inside the culverts to the average velocity in the adjacent stream reaches. In order to do so the following data will be calculated:

1. Average velocity in the stream channel at a typical cross-section up and downstream of the culvert over a range of discharges.
2. Average velocity at the inlet, outlet and inside the barrel of each culvert over a range of discharges.

STUDY DESIGN

Successful Passage through Culvert

There will be two assessment periods. The first will be before culvert replacement (June 2013-June 2014) and the second after replacement (July 2014 through October 2015). For each assessment period, we will use PIT tags to mark up to 1,200 fish for a total of 2,400 marked fish over the course of the study. As the main objective of this study is to observe the upstream movement of juvenile fish through the culvert fish will be captured in Buddy Creek, downstream of the study site. At least one trapping event will take place in Montana Creek each year in order to tag fish that were spawned there and may move into Buddy Creek later in the year. We expect to see fish movement year round but we predict that much of the observed upstream movement of young of the year fish will occur will occur between late July and October as coho move into rearing and overwintering habitat (Jon Gerken, USFWS, personal communication). Coho are known to rear and overwinter in wetland complexes and beaver dams and there are extensive wetland and beaver complexes upstream of the study site (REF).

Buddy Creek is a clearwater snowmelt driven system and we predict two periods of high flows: one occurring in the spring driven by snowmelt in the watershed and one in the late summer and fall driven by rain events. Low flows will occur during the winter. A hydrograph from nearby Willow Creek is shown below as an example of the type of hydrograph we expect at Buddy Creek, although measured discharges will be much lower in the smaller Buddy Creek than in Willow Creek. Summer base flows are also likely to be relatively smaller in Buddy Creek as the watershed is smaller and at lower elevation with snow unlikely to persist past early June.

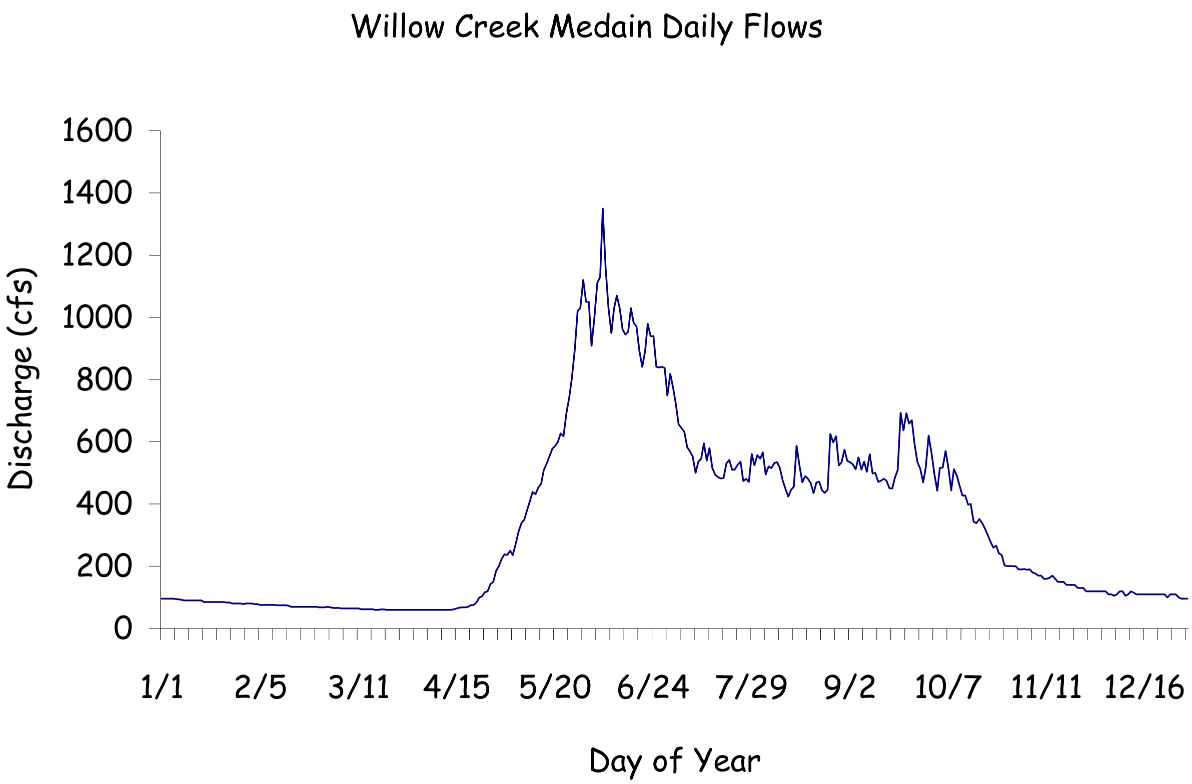

Figure 8. Hydrograph showing median daily flows at Willow Creek, Willow, AK.

DOWL HKM carried out a hydrologic study of Buddy Creek approximately 2 miles upstream of the study site in support of another culvert replacement and estimated the following peak runoff flows using the USGS regression analysis (DOWL HKM 2012)

Table 1. Estimated peak runoff flows for Buddy Creek at Kathadin Rd.

Storm Event (year)	**Storm Size (cfs)**
2	60
5	96
10	123
25	161
50	192
100	224

cfs = cubic feet per second

The bankfull discharge in an alluvial defined as being equal to 1.5 year storm or return flow which was calculated as approximately 60cfs two miles upstream of the study site. Direct measurement of discharge at close to bankfull flows in May of 2013 allowed us to refine the estimated bankfull discharge at the study site to approximately 100-110cfs. Discharges greater than approximately 110cfs will therefore result in water leaving the channel and spilling into the adjacent floodplain.

Ordinary High Water (OHW) is a lower flow than bankfull and typically occurs each year, often several times, during peak runoff periods. OHW is defined by the State of Alaska based on physical changes to the channel:

The "Portion of the bed(s) and banks, up to the ordinary high water mark (OHW)" means

- (A) in the non-tidal portion of a river, lake or strea: the portion of the bed(s) and banks up to which the presence and action of the non-tidal water is so common and usual, and so long continued in all ordinary years, as to leave a natural line or "mark" impressed on the bank or shore as indicated by erosion, shelving, changes in soil characteristics, destruction of terrestrial vegetation, or other distinctive physical characteristics;
- (B)in a braided river, lake, or stream: the area delimited by the natural line or "mark," as defined in Part A above, impressed on the bank or shore of the outside margin of the most distant channels; or
- (C) in the tidally influenced portion of a river, lake, or stream: the portion of the bed(s) and banks below the
    1. OHW as described in A or B above, or
    2. mean high water elevation; whichever is higher at the project site.

A discharge measurement taken in June 2013 at close to OHW allowed us to refine the estimate of ordinary high water (OHW) discharge to between 60 and 80 cfs.

We will continue to refine these estimates throughout the study by collecting frequent discharge measurements until we are able to relate terms such as OHW, base flow, winter base flow etc to a narrow range of discharges.

For this study we will concentrate on discharges less than bankfull flow for two reasons: water and fish may be able to bypass the culverts and SPIs at higher flows and juvenile fish are unlikely to move at very high flows. Therefore we expect to monitor fish movement during the open water season over a range of discharges approximately equal to 10-80cfs and in the winter season discharges less than 20cfs. If discharges greater than bankfull occur during the study period we will suspend data collection for that period.

The instream SPIs will remain in place for the entire project duration, will be removed for the culvert replacement project and reinstalled afterwards to allow monitoring of previously tagged juveniles that may still be present.

Fish will be captured using baited minnow traps. Length measurements (fork length) will be recorded for all captured juvenile Chinook and coho salmon fry and Dolly Varden or other trout. Fish greater than 65mm (fork length) will be marked with PIT tags (12.45mm super tag, 134.2khz); all others will be released as it has been shown that fish of 55mm lengths have reduced tag retention and detection, as well as overall performance (McCann et al. 1993). The size of tag was chosen based on recommendations from the manufacturer Biomark and other practitioners (Jenny Cope, ADFG Sport Fish, Soldotna, pers comm & Jon Gerken, USFWS, pers comm).

The focus of this study will be on juvenile coho salmon, which are the “model fish” for the majority of fish passage assessments on the West Coast and we anticipate capturing and tagging up to 1,000 juvenile coho each year. We also anticipate catching juvenile rainbow trout and tagging up to 250 each year. Any Chinook are captured in the minnow traps they will be tagged but at this time we do not anticipate catching large numbers. If the composition of the fish population is considerably different than anticipated, if juvenile Chinook salmon are more common in Buddy Creek than anticipated, we will revise the tagging goals to include both Chinook and coho salmon.

Tagging will begin when the equipment is installed in June and will target one year old fish already present in the system. Beginning in mid-July of each year, when lengths for YOY are within the acceptable size range, we will capture and tag YOY fish.

Data for each marked fish will include:

1. a unique tag code
2. tagging date
3. capture and release location - identified by distance (m) from the culvert (inlet or outlet, as is appropriate)
4. species
5. fork length (mm)

Data collected from the SPIs include

1. a unique tag code for each fish detected
2. time and date of detection
3. location of detection (known location of SPI)

When a fish is detected at the downstream SPI followed by the upstream SPI we will know that it has successfully passed through the culvert(s) and the time and date that passage occurred. This along with the data collected from the stream gage will allow us to achieve Objective 1.

Sample Sizes

We plan to distribute 1,200 tags per year. Based on the existing fish data for Buddy Creek (ADF&G*, In Prep*) we expect to capture primarily coho salmon and rainbow trout in Buddy Creek and coho and some Chinook in Montana Creek. Our goal is to maximize the number of tagged fish that remain in the system to be monitored so we will focus on YOY fish. We will however tag age 1+ fish early in the season in order to tune and test the tagging equipment as well as collecting data on the movement of larger juvenile fish.

We plan to tag fish as follows each year:

- 1,000 coho juveniles between 65 mm and 110 mm
    - 750 coho juveniles between 65-85mm at time of tagging.
    - 250 coho juveniles between 86 mm-120 mm at time of tagging.
- 250 juvenile Chinook between 65 mm and 85 mm in the first year of the study.
  If no Chinook are observed in Buddy Creek we will not tag Chinook the second year.

All fish will be tagged between July and September; no fish will be tagged during the winter due to the risk of mortality. We predict that overall movement of YOY fish in the study area throughout the tagging period will be upstream in search of good overwintering habitat, known to exist upstream in the large beaver complexes. Therefore the majority of our observations of upstream fish movement are predicted to take place during the summer and fall section of the hydrograph with flows estimated to range between 20-30cfs in July (mid-summer base flows) and 60-80cfs in the fall rainy season. We plan to tag fish in July, August and September, over a period of approximately 10 weeks. In order to capture fish movement over as wide a range of discharges as possible we will spread tagging effort evenly throughout that period, tagging 250 fish over a 1-3 day period every 15-20 days. The exact dates will depend on the date at which YOY fish achieve our minimum size of 65mm.

Although tag retention and initial survival in juvenile salmonids is generally in the 95%+ range (King, In Prep; Gries and Letcher, 2002) studies that follow juvenile salmonids until outmigration report detecting as many as few as 25-42% of the tagged fish over time due to predation, emigration, mortality and tag loss (J. Gerken, USFWS pers comm; Peterson et al 1994). Additionally in this study fish will be tagged outside the project area and we will only detect those fish that move into the project area, fish tagged downstream of the study area may or may not attempt to move upstream. Assuming a 60% loss of tagged fish over time and a conservative estimate of the variance ration of 2 (Table 2), the number of fish needed to be tagged to meet the objective criteria is 250 each year (Figure 9). The planned sample size of 750 is more than sufficient to meet the objective criteria for all planned and contingent data analysis.

Table 2. Assumptions used to estimate sample size for Objective 1.

Time	Estimated Range of Flow With Successful Passage	Estimated Variance of Flow With Successful Passage	Ratio v_1/v_0
Before (v_0)	10 - 50	100	4.0
After (v_1)	10 - 90	400	

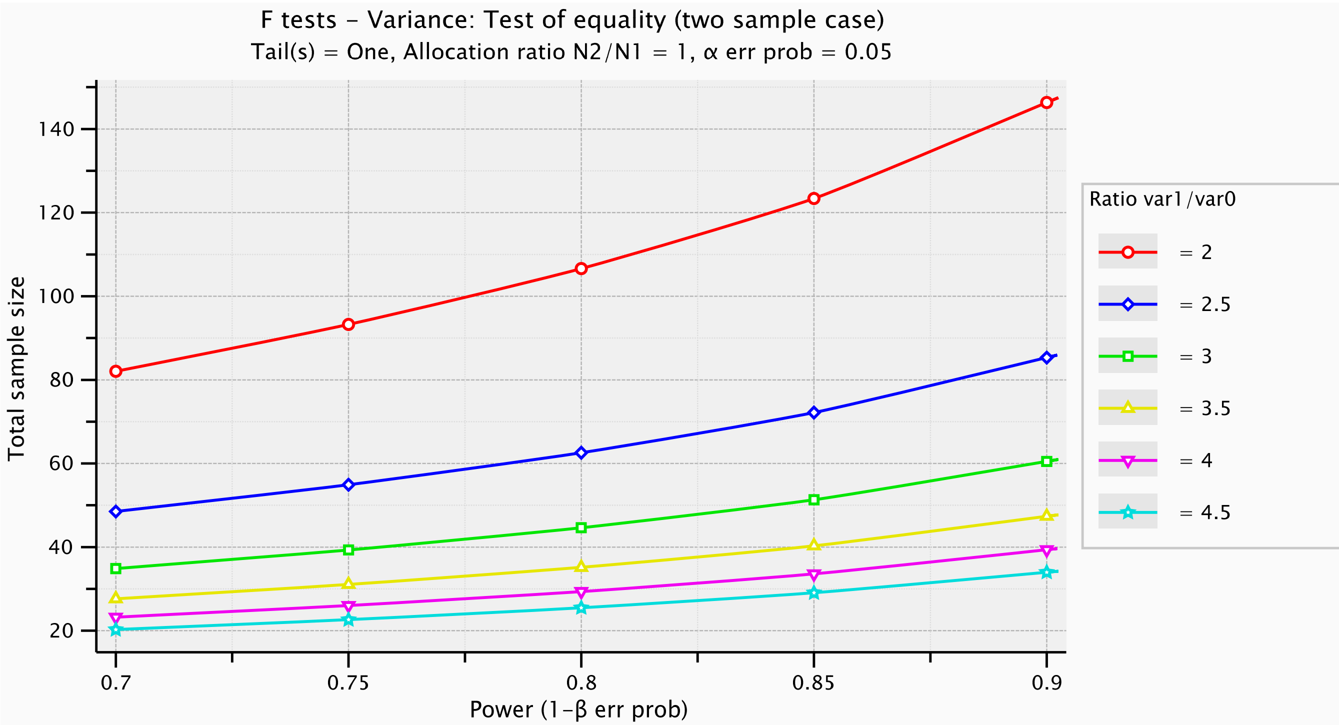

Figure 9. Sample size requirements for Objective 1.

Velocity comparison

To test the hypothesis that average velocities inside the culverts will increase at a greater rate than in the adjacent stream channel as discharges increase we will follow the methods described in Klein 2013 to determine overall stream discharge and will proportion discharge to the culvert based on occupied cross sectional area.

During the open water months the average cross sectional velocity of the water in the natural stream channel will be compared to the average cross sectional velocity of water inside the culverts both before and after replacement. Average cross sectional area will be calculated from the discharge at a cross section of known shape and area using the equation:

$$Q=VA$$

where:

Q = discharge
V = average cross sectional area a
A = area of cross section

Average velocity in the natural channel will be calculated at the gage station where we will be establishing a permanent cross section used to calculate discharges. We will calculate the average instream velocity for discharges up to the bankfull discharge, at which point flows will be outside the channel and the cross sectional area of flows will be unknown.

During the pre-replacement period we will need to establish how much of the total discharge goes through each culvert over the entire range of flows. We will do this by measuring the area of the water inside each pipe over a range of discharges, on a weekly basis throughout the open water period, in order to create three curves that relate the overall stream discharge to the proportion of that overall discharge moving through each culvert (cfs). Once we have established those three curves we can estimate discharge in each pipe at any overall discharge and calculate the average velocity for each culvert.

We will establish staff gages at the inlet and outlet of each culvert and permanent cross sections inside the barrel and calculate average velocities at each of those nine locations.

In order to estimate the accuracy of the above method we will also use an acoustic Doppler velocimeter and wading rod to measure water velocity at the culvert inlet, outlet, and in the barrel, where possible, and in the natural channel at the gage location. This data can be used to build an independent correlation between velocities inside the culverts and in the stream channel for comparison.

After the existing crossing has been replaced we will install a stream gage inside the new stream simulation culvert and use that to collect discharge measurements at 15 minute intervals that we can use to compare to data collected at the gage site downstream.

Sample Sizes

In order to build a stage-discharge relationship a minimum of three discharge measurements are needed at low, medium and high flows. We anticipate collecting a minimum of 10 discharge readings over a range of flows during the open water period each year. We also anticipate collecting a minimum of 10 stage readings at the culverts both open water seasons and carrying out 10 spot velocity collections.

DATA COLLECTION

Site Characteristics

The crossing will be surveyed using the standard ADF&G Fish Passage Level 1 methodology as described in Eisenman and O'Doherty (In review) both before and after replacement.

Successful Passage through Culvert

Two project personnel (FBIII and FBI) will be primarily responsible for collecting data associated with monitoring seasonal fish behavior. During the third week of June 2013, the project leader will work onsite with staff from ADF&G and USFWS to install the two SPIs (and related equipment (antennae, transceiver enclosures, multiplexers, power supplies, data loggers, interfaces, generator). A propane generator will be used to provide power to the PIT tag system. ADF&G staff will also install the hydrology equipment at this time.

Once installation has been completed, each SPI will be tested for tag detection by attaching a PIT tag to a small wooden block and allowing this to float through the SPI. The watered plane of the SPI will be divided into a 5 x 3 grid: 5 columns across the channel and 3 rows deep. The tag will be passed through each surface grid section 10 times, 5 moving in a downstream direction and 5 in an upstream direction. The block with tag will then be weighted so that it becomes submerged near the middle of the water column and again near the substrate, with tests being repeated. Each antenna will have a total of 150 tag passes. (Form: Appendix A). We will repeat this test every 7-10 days throughout the open water project period.

Once PIT equipment has been tested and shown to be operational we will begin trapping fish and deploying tags (late June 2013 through September 2013). Fish will be captured at several locations downstream of the culvert using baited minnow traps. Since YOY fish are being targeted for tagging, it is important to check traps at about 30 minute intervals to avoid loss by exiting the trap or through predation by larger fish (Kane et al. 2000).

A portable tagging station will be set up along the streambank. The tagging station will consist of a roll-a-table, tagging equipment, two rectangular plastic dish tubs (3 gallons, dark colored), and two rectangular plastic totes (~20 gallons, dark colored, perforated sides). Fish will be retrieved from a single trapping location and placed in a rectangular tote for transport to the tagging station. If the number of fish trapped is too many to be safely anesthetized and processed within 5 minutes, then excess fish will be placed in a rectangular tote anchored to the streambed. This tote will have small perforations to allow ample water circulation. Lengths will be recorded for all salmonids captured and fish greater than 55mm will be tagged. (Form: Appendix A)

Tagging procedures will follow the protocol of the Columbia Basin Fish and Wildlife Authority PIT Tag Steering Committee (PTSC) (1999) and recommendations of USFWS personnel who are carrying out a similar project in Meadow Creek. The tagging team will consist of one person recording data and one person tagging. Fish to be tagged will be placed in an anesthetizing bath using tricaine methanesulfonate (MS-222). The recommended MS-222 solution will be approximately 40mg/l (Schoettger and Julin 1967) but this will vary with water temperature, fish species, and stress level of fish. Induction time to the anesthetic is about three minutes with fish being ready for tagging when they roll over on their sides. A Biomark ® MK-25 implant gun will be used to inject the PIT tag (TX1400ST, 134.2khz, 12.45mm super tag). An anesthetized fish will be selected from the work tub and scanned with a FS2001 ISO READER to determine if the fish was previously PIT tagged. With the fish turned ventral side up, the person tagging will hold the fish in one hand with the head toward the wrist and the tail between the thumb and index finger. The needle will be positioned between the posterior tip of the pectoral fin and the anterior point of the pelvic girdle. The puncture will be 1-2mm from the mid-ventral line with the tag being inserted into the ventral area of the abdominal cavity. The fish will then be scanned to enter the PIT tag code and a fork length measurement will be taken. The fish will then be placed in the recovery water bath (dish tub). The person responsible for data entry will record fish species, length, tag date, capture and release location, and other relative information. Lengths for all salmonids will be recorded, but only those in the desired length range (greater than 65mm) will be tagged. When all fish from that batch have been processed, fish will be transferred to the stream and held in a perforated recovery tote for approximately 30 minutes. While these fish recover another trap will be checked and fish retrieved for tagging. When the next batch of fish has been processed, the previous batch will be returned to their capture location and released. The process will continue in this manner.

Density of juvenile salmonids in Buddy Creek is unknown so the capture per trap may be small. Because of these limiting factors, it is anticipated that we may only tag 100-150 fish per day.

To expedite streamside tagging, the PTSC recommends pre-scanning each tag before going to the field. The tag numbers can be printed on a write-in-the-rain data form used for other data, or entered into an EXCEL spreadsheet created for data entry. Onsite transcription of tag codes is not recommended due to a high, unacceptable error rate. We will follow this protocol.

Once tags are deployed and detection begins, data will be downloaded from the data logger on a weekly basis and all equipment will be checked at that time to make sure it is functioning correctly. Equipment may be monitored more frequently at times of increasing stream discharge or icing and, if necessary, equipment may be removed due to high flow or icing.

We will monitor fish passage until construction on the replacement culvert begins, likely mid-June, 2014. During construction the SPIs will be removed. When installation of the new culvert has been completed (mid July 2014), we will reinstall the SPIs at the same locations, as close to the culvert as possible without interference from the structure. Once installation of the SPIs has been completed and checked (as above), monitoring of fish will continue. We will deploy an additional 1,200 from June to August of 2014 tags following the methods described above. Monitoring will continue throughout the year until October 30th 2015 or until iceup, whichever occurs first when the equipment will be removed and stored.

Velocity Comparison

In order to record stream discharge and meet objective 1, a staff gauge and vented pressure transducer (OTT Orpheus Mini) will be installed along the stream bank upstream of the culvert inlet. The transducer will record water level (stage) to 0.01ft at 15-minute intervals. We will collect discharge measurements using a FlowTracker Acoustic Doppler Velocimeter at a range of low, medium and high water levels in order to develop a stage/ discharge relationship. This data will be used to generate hourly average discharge.

In order to meet Objective 2 and compare average velocities inside the culverts to average velocities in the adjacent stream channel we will create an area / discharge rating curve for each culvert. Stream cross section measurements (nearest 0.01m) for area of the water will be collected using standard USGS protocol (Carter and Davidian 1969) at a range of discharges. At a range of discharges, we will visually inspect and record stream stage height (0.01m) at each end of the culvert and inside the barrel, calculate the area of the culvert occupied by water and use this to create an area/discharge relationship for each culvert in the crossing. We will test this relationship by measuring the velocities at each culvert with a FlowTracker Acoustic Doppler Velocimeter and comparing to the known stream discharge.

DATA REDUCTION

PIT tag data will be uploaded from the data logger and error checked for correct date, time, and location of fish. Data will be entered into EXCEL for summaries and analyses. Stream and hydrology data will be entered into EXCEL spreadsheets. Final edited copies of the data and a data map will be archived on the Division's Intranet Docushare website-the filename and directory is yet to be determined.

DATA ANALYSIS

Successful Passage through Culvert

The F-test will be used to test the hypothesis that successful passage of juvenile coho salmon will be observed over a wider range of stream discharges after the existing crossing is replaced with a stream simulation culvert. Specifically, we will test the null hypothesis that the variance of stream discharge with successful passage is the same before and after the crossing is replaced against the alternative hypothesis that that the variance is greater after the replacement.

$$F = \frac{s^2_{after}}{s^2_{before}}$$

where:

s^2_{after} =	variance in discharge rate of successful passage after the culvert has been replaced
s^2_{before} =	variance in discharge rate of successful passage before the culvert has been replaced

An assumption of the above F-test is that both data sets are normally distributed. If the data does not meet this assumption either Levene's test or Brown–Forsythe test will be used depending on the distribution of the data.

Velocity Comparison

Pre-replacement four area / discharge rating curves will be calculated; one using the combined area of the culverts and one for the area of each individual culvert occupied by water (K_{area}):

$$K_{area} = r^2(\theta - \sin\theta)/2$$

where:

r =	radius of pipe,
d =	distance from the center of culvert (in cross section) to water surface
=	r-h (empirical observation)
h =	measured water depth from culvert invert (inlet and outlet) (empirical observation)
θ =	2 arccos(d/r) (in radians)

Using these cross section estimates for water in the culverts ($K_{area} = A$) and discharge (Q, estimated at the gauging station), we will estimate average velocity (V=Q/A) across the structure as a whole and at each individual culvert inlet and outlet and inside each barrel over a range of discharges.

After the crossing is replaced we will calculate another area/discharge rating curve for the new culvert using the same methodology.

Velocity (f/s) will similarly be estimated for the midpoint of the stream cross-sections located at the gaging site. Using the stream area cross section collected at a range of stage heights, we will develop an area / stage relationship to estimate V as Q/A with Q determined by discharge.

SCHEDULE AND DELIVERABLES

PIT equipment installation	June, 2013	O'Doherty, Eisenman, technician
PIT tag deployment	July-September, 2013	O'Doherty, Eisenman
Fish monitoring	July 2013 – October 2015	O'Doherty, Eisenman
Hydrology/Stream data collection	July 2013 – October 2015	O'Doherty, Capiello
Data entry	continuous	O'Doherty, Eisenman, technician
Pre-Culvert replacement data analysis	January 2015	O'Doherty
Annual operation plans	May 15, 2014 and 2015	O'Doherty
Final report	February, 2016	O'Doherty

When the 2 year assessment has been completed, the results of this project will be presented in an Alaska Department of Fish and Game, Sport Fish Division, Fishery Data Series report.

RESPONSIBILITIES

Gillian O'Doherty Habitat Biologist III:
This position will be project leader for this research. This position will author the project operational plan and manage the budge, hire project personnel and supervise their activities. She will be responsible for collection and analyses of the fisheries related data. This person will conduct necessary repairs and maintenance of equipment. This position will assure that project objectives and timelines are met. She will work with biometric staff to conduct data analyses. She will author an annual summary report of project progress, to be provided to the granting organization. At the conclusion of the project, she will author a formalized report to be published in the Alaska Department of Fish and Game, Sport Fish Division, Fishery Data Series.

Mark Eisenman, Habitat Biologist I:
This position will assist the project leaders in fisheries, hydrology, and stream data collection. Other responsibilities include review of field data, data entry, and as time permits, data analyses and summaries.

Neil Durco, Technician:
These positions will assist the project leaders in fisheries, hydrology, and stream data collection.

Tom Cappiello, Habtiat Biologist III:
This position will be responsible for installation of the stream gage, helping collect hydrology data training other project personnel in the collection of hydrology data.

Pat Hansen, Biometrician III:
This position will provide biometric support for operational planning, data analyses, and reporting.

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